A NOVEL DEVICE FOR DISSEMINATING FIRE-EXTINGUISHING AGENTS

by

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BACKGROUND

It is generally believed that, because of its ability to absorb large quantities of heat, a mist of water droplets would be an excellent fire-extinguishing agent. However, a mist has two distinct disadvantages.

The first disadvantage is the fact that a water mist is a streaming agent. In order for it to work effectively the location of the fire must be known ahead of time in order to orient the system with the location in mind. The other alternative is to manually direct the mist toward the fire; however, this requires operator interaction after the fire starts. which defeats the purpose of an automatic fire-extinguishing system. In either case, to achieve maximum efficiency of the water mist, the location of the fire must be known, either before or during the event. If there is the possibility of a fire in multiple locations in a given area, then either multiple streaming agents or a three-dimensional agent is needed.

When discharged, a three-dimensional agent will flood the enclosure it is in. With this flooding effect it is more likely the agent will reach a fire that is not directly in front of the discharging nozzle. Gaseous agents such as halon 1301 and carbon dioxide (CO_2) are good three-dimensional agents. However, the ozone-depletion problems associated with halon 1301 are well known. Using CO_2, the concentrations needed to extinguish a fire are too high to consider it as a viable fire-extinguishing agent in locations that are considered occupied.

The second disadvantage of a water mist is the size of the particles. The most effective mist is one that has very small water particles. With smaller particles. the ratio of the surface area to the volume of each droplet is greater. This larger ratio increases the heat transfer rate from the flame zone to the water droplets. Increasing the heat transfer rate reduces the flame temperature faster, which in turn extinguishes the fire with less water.

However, the disadvantage of a fine mist of water droplets is the ability to spray the mist. Water droplets are not very aerodynamic, and the smaller the particles the less mass they have. Nonaerodynamic, low-mass droplets are difficult to propel a fine mist of water very far. This requires the designer of the fire-extinguishing system not only to know where the location of the fire is but also to locate the system close to the anticipated flame zone.

INTRODUCTION

A device that is capable of dispersing a water mist throughout a volume has been constructed, Therefore, the water mist can act as a three-dimensional agent, much like gaseous agents. This idea of this device is to disseminate a high volume of fine droplets of water in such a way as to make the water droplets permeate an enclosure.

The device consists of two equally pressurized cylinders, fast-acting solenoid valves, a mixing chamber, and the necessary hardware to complete the system. One cylinder contains a vaporizable liquid, such as FE25 or CO_2, and the second cylinder contains a liquid agent such as water or a water-based solution. The cylinder containing the water is pressurized with CO_2 or nitrogen. Upon activation of the solenoid valves, two liquid streams (CO_2 and water/water-based solution) are directed into a static mixing chamber, such as a vortex mixer. The two streams are blended intimately in the chamber. Upon exiting the mixer, into a nozzle, the vaporizable liquid flash evaporates and expands throughout the volume of the enclosure. This expanding gas carries droplets of the liquid agent with it as it permeates the volume. The droplets of liquid act as the principal fire-extinguishing agent.

The vaporizable liquid (in the gaseous state) can contribute to the fire-extinguishing process; however, its main purpose is to act as a carrier for the liquid fire-extinguishing agent. This limits the amount of vaporizable agent required to the amount needed for dissemination. This will allow use of the vaporizable agent in small enough quantities that it does not exceed the No Observed Adverse Effects Level (NOAEL). The high aerodynamic drag of the small droplets is an advantage, as they are swept along by the expanding gas as it moves throughout an enclosure.

DESCRIPTION OF DEVICE

An illustration of the device is shown in Figure 1. For the purpose of experimentation, the device consists of two sections, a stationary section that is permanently connected to the experimental chamber and a removable section.

The removable section consists of two modified 15-lb fire extinguishers. The standard head and valve assembly is removed from the bottles, and a separate valving system is installed. The modified valving system consists of a gate valve, an overpressure disk for safety reasons, and a union for quickly disconnecting the cylinders from the stationary portion of the system for refilling purposes.

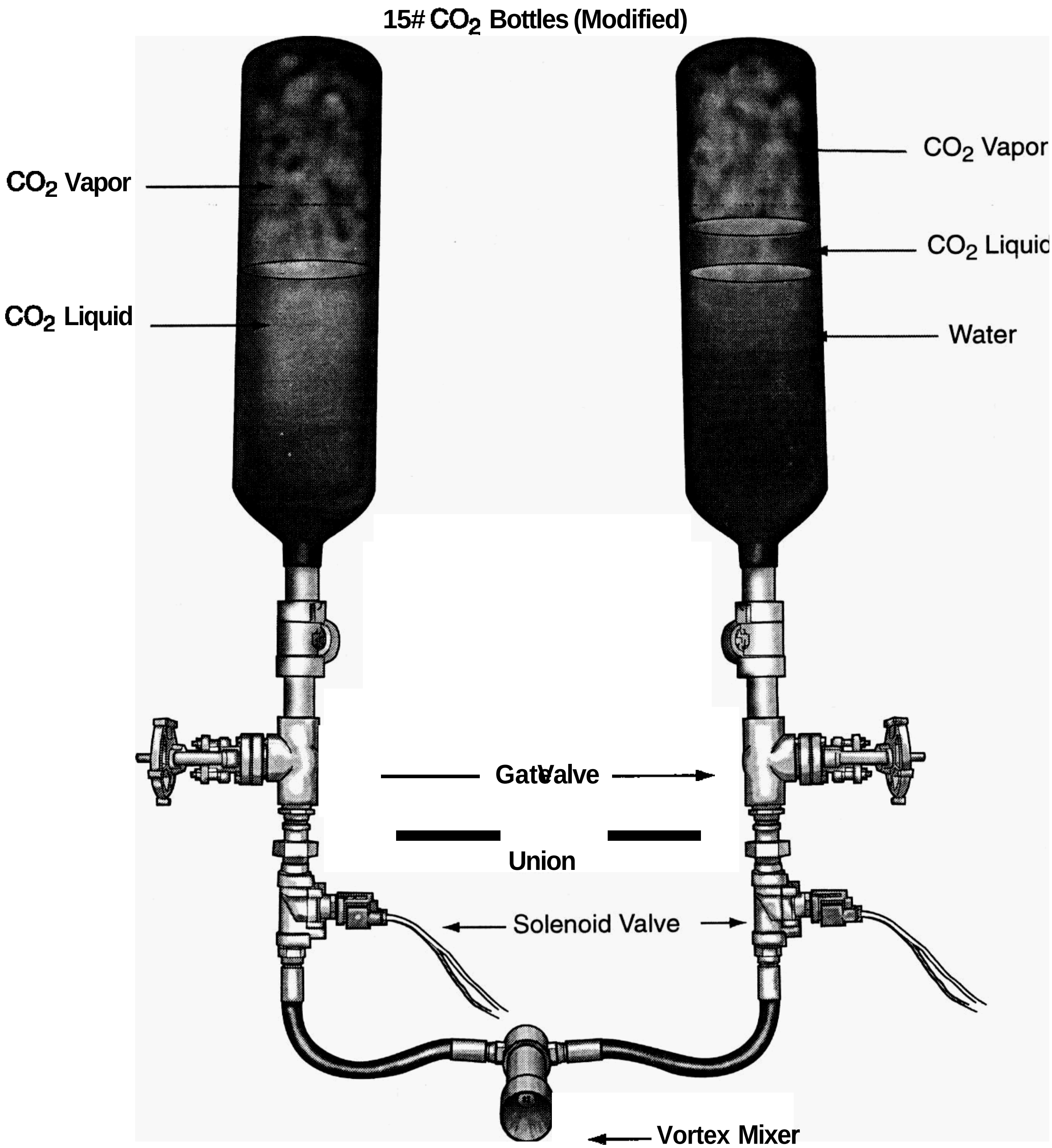

Figure 1 Illustration of Experimental Device

The valving system on both cylinders is identical. Directly out of the cylinders is a 1-inch-diameter stainless steel nipple. This nipple leads into a I-inch stainless steel tee. In the other two sections of the tee are another one inch nipple and a stainless steel plug. The plug is modified to receive a copper burst disk that Will rupture if there is an overpressure in the cylinder. The disk used is a standard disk used for the 15-lb carbon dioxide fire extinguishers. The I-inch nipple leads into a cast-iron gate valve. The gate valve is used to seal the cylinder after it is filled yet it does not restrict the flow when in the fully open position. Following the gate valve are two reducers that reduce the diameter from I-inch to ¾ inch and then to a ½ inch. A %inch nipple follows the reducers and leads into the male end of a disconnect union. This union is used to simplify disassembling the system after each experiment in order to fill the cylinders.

The stationary portion of the system starts at the female end of the union. Following the female end of the union is a fast-acting solenoid valve. The solenoid valve is followed by a %inch flexible hydraulic hose. The hydraulic hose from both the cylinders leads into a mixing chamber.

That is the initial configuration of the system. However, future experiments include the investigation of mixing chambers with diameters larger than a ½ inch. This will require modifications of the system beyond the gate valve.

MIXING CHAMBER

The static mixer is the location where the two liquids (CO, and water) are mixed. Both liquid CO, and water enter the mixing chamber as two distinct streams. Within the chamber, the two streams are intimately mixed to produce a homogeneous mixture. This homogeneous mixture then exits the mixing chamber into a nozzle, where the CO, flash vaporizes, creating a fine mist of water throughout the CO, gas.

Various static mixers will be utilized to determine the characteristics of each chamber. One device to be utilized is an interfacial surface generator (ISG) motionless mixer available from Ross Engineering. This is an in-line mixer that consists of individual mixing elements enclosed in a housing. Four holes are bored in each element to allow for the flow, and the ends of the elements are machined to create a tetrahedral chamber between two elements. Within the tetrahedral chamber, the exit holes of one element are in a linear array 90" from the linear array of the entrance holes of the adjoining element. This mixer is illustrated in Figure 2. The mist of water droplets within the CO_2 vapor cloud after exiting the mixer is shown in Figure 3.

This particular mixer offers mathematically predictable layer generation. The layer generation is the number of layers created at the exit side of an element As an example, this device has two inlet streams entering four holes in the first element. Exiting the first element will be eight layers. Now eight layers are entering four holes in the second element. At the exit of the second element will be 32 layers.

The number of layers emerging from an element are calculated based on the formula[1]

$$L=N(4)^E$$

[1] Ross Engineering, Inc. Literature, Ross Engineering, Inc., 32 Westgate Blvd. Savannah, GA 314051475

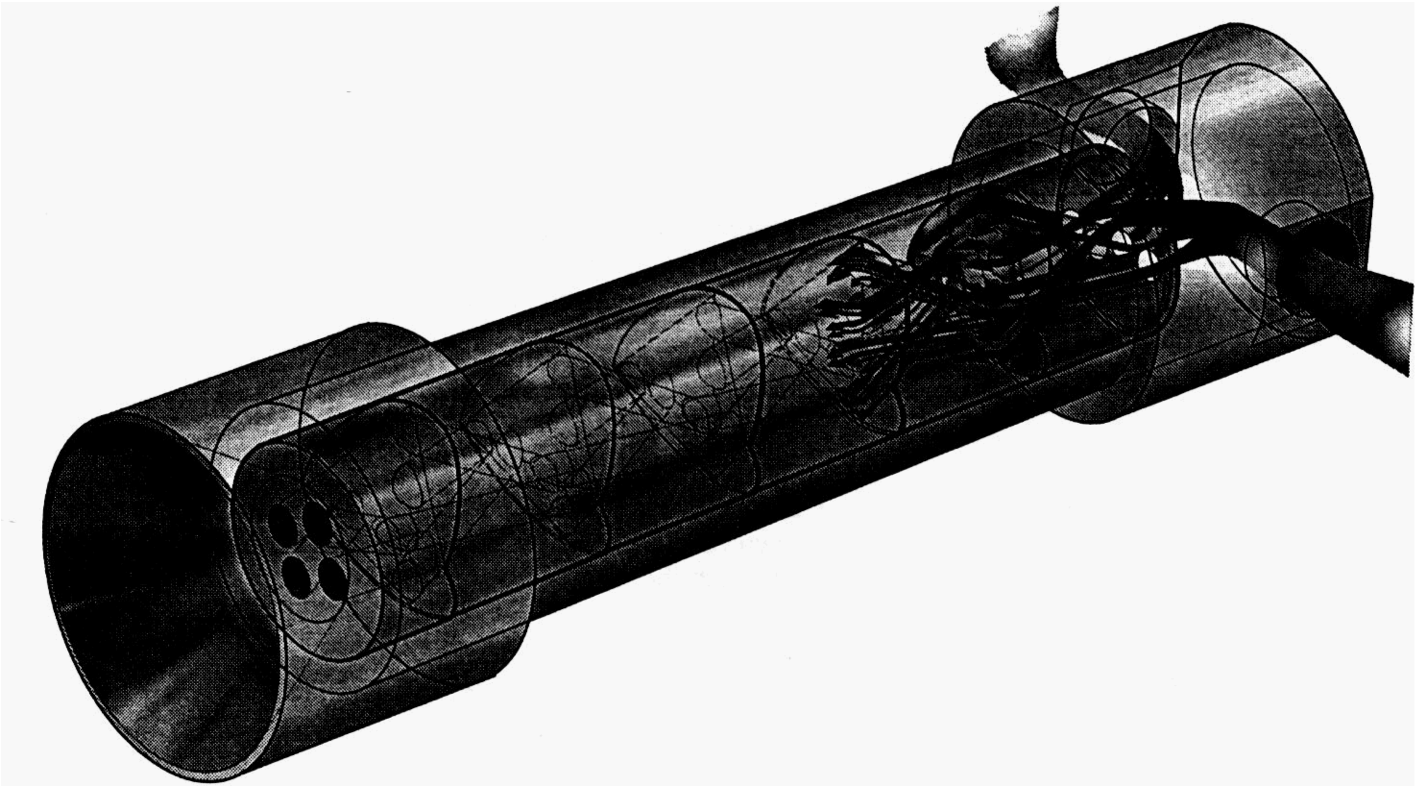

Figure 2 Mixing of CO_2 and water

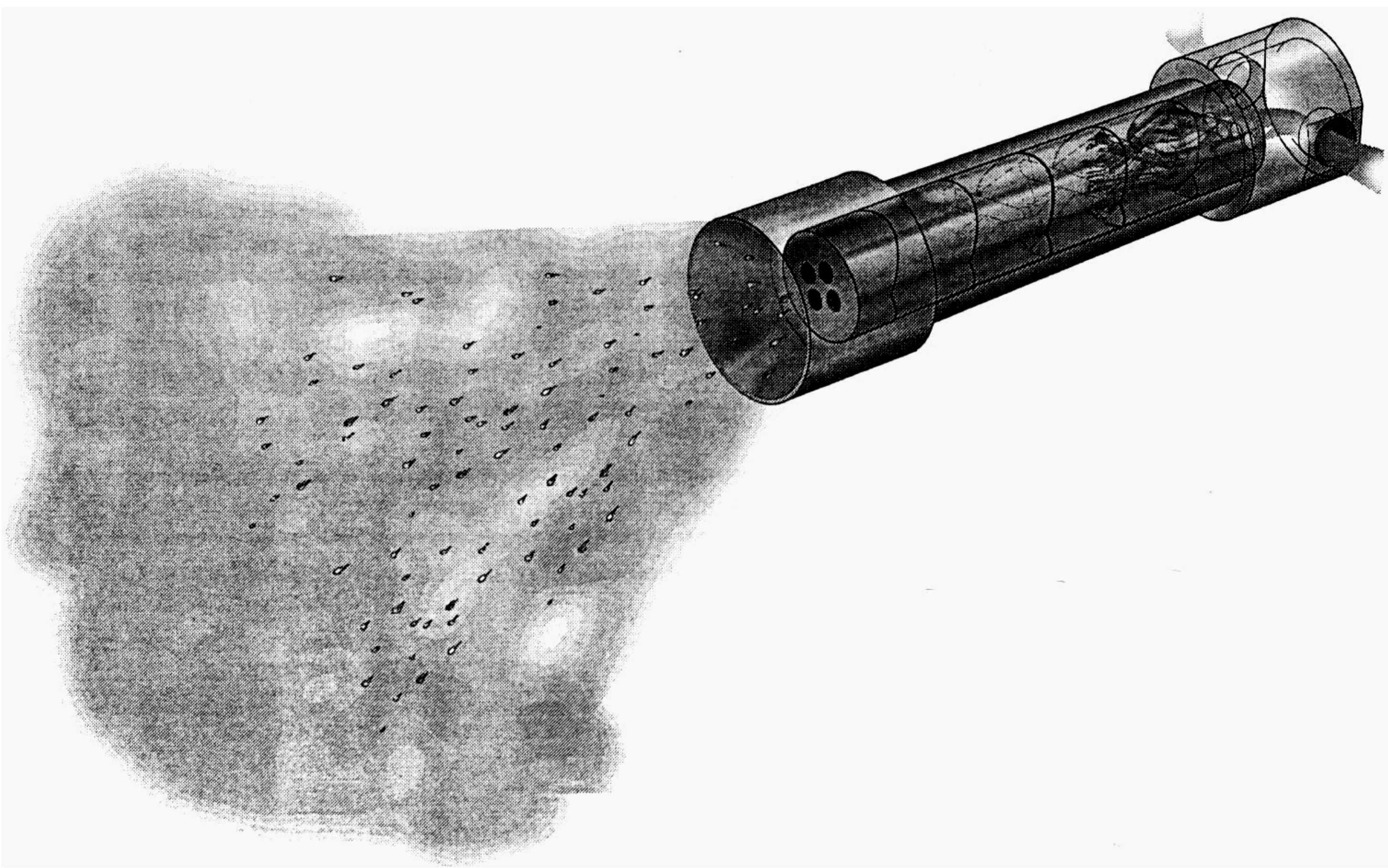

Figure 3 Water droplets within the CO_2 vapor

Where

L = number of layers created,
N = number of initial input streams (two for this device), and
E = number of elements.

The number of elements in the array will be varied in order to determine how the number of layers created affects the output of the device. As a starting point, five elements will be used, which will yield **2,048** layers.

$$\mathbf{L} = 2^*(4)^5 = \mathbf{2{,}048} \text{ layers}$$

These mixers are available in various diameters. As stated previously the initial installation will have five %inch-diameter elements. Variations of the mixing chamber will include changing the number of elements and using different diameter elements.

Other mixing chambers are commercially available. Mixers other than the ISG mixer will be investigated to determine their effectiveness with this device.

CONCEPT OF DEVICE

The concept of the device is to store liquid CO_2 and water (or a water-based material) in separate cylinders. When the fire-extinguishing agent is needed, liquid water and liquid CO_2 are mixed in the mixing chamber. Upon exiting the chamber, the CO_2 flash evaporates and fills the enclosure as it normally would when released into an enclosure. However, the liquid mixture also contains water or a water-based liquid. As a result of the flash vaporization of the CO_2, a fine mist of the waterhater-based liquid is created. The large aerodynamic drag associated with a fine mist of water will now be a benefit. Typically the large aerodynamic drag of a water mist is a disadvantage because it is hard to propel very far. However, in this case the CO_2 is expanding and filling the enclosure at the same time the fine mist is being created. As a result of the large aerodynamic drag, the CO_2 will carry the water mist with it as it expands throughout the enclosure.

In order to accomplish this objective one cylinder is filled with CO_2. This cylinder is inverted as shown in Figure 1 in order for the liquid CO_2 to exit the cylinder through the valving system and into the mixing chamber. The water/water-based solution is added to the second cylinder. After the water is added, the cylinder is pressurized with CO_2. This cylinder is also inverted in order for the water/water-based solution to exit the cylinder.

DATA COLLECTION

Various parameters of the device will be modified to determine the optimum configuration. For the various parameters extensive data will be collected for comparison of the different configurations. The data that will be collected will include the droplet size, the droplet distribution with respect to location and time, the concentration of CO_2 in the enclosure, etc.

In order to collect these data, several tools will be used. The first data collection tool is microscope slides. Nine microscope slides will be coated with a thin layer of silicon grease. The silicon grease will help collect the water droplets on the slide. These slides will be placed on a stationary circular disk Directly above the circular disk with the microscope slides will be another circular disk The upper disk has a single window in it to allow for water droplets to pass through and settle on the microscope slide below. This window is slightly smaller than a single microscope slide. The upper disk with the window is on a shaft, which allows it to rotate. This rotation is computer controlled and will expose a given microscope slide for a predetermined time. The disk will then rotate and close all the slides or open another slide depending on the data required for a given experiment This microscope slide window configuration will allow for the collection of water droplets on nine separate slides at various times. This device also controls the amount of time any given slide is exposed. This will allow for the analysis of droplet size with respect to time of exposure and duration of exposure at a given location within the enclosure. With this device we will be able to determine the initial size and concentration of the water droplets. We will also be able to determine if and how they are changing in size and concentration with respect to time. A drawing of the microscope slide setup is shown in Figure 4.

Another data collection device that will be utilized is drying tubes. Drying tubes will be placed throughout the enclosure to measure the quantitative amount of water at a given location. A schematic of the drying tube setup is shown in Figure 5.

The drying tubes will collect data from five locations within the enclosure. At each location there will be 9 drying tubes, for a total of 45 drying tubes per experiment. This will allow for the determination of water concentration at five locations at nine different time intervals. This will indicate the concentration of water immediately after discharge of the cylinders and at interval times following the discharge of the cylinders.

The setup of the drying tubes consists of a drying tube filled with an absorbent material and porous plugs. The weight of the drying tube is measured prior to the experiment. Following the drying tube is a flow restricter. The flow restticter limits the flow of air to a manageable amount with respect to the vacuum pump, which is further downstream of the flow. Tubing is connected to the flow restricter, which leads into a manifold. Nine of these drying tube setups lead into a single manifold. At the beginning of the manifold is a valve. This valve starts or stops the airflow to the nine drying tubes.

A single manifold contains five drying tubes. These drying tubes are located at five separate data collection locations within the enclosure. This manifold system with drying tubes is repeated nine times. This yields 45 drying tubes, which is 9 drying tubes at 5 locations. The nine manifolds are connected to a central accumulator which is connected to a vacuum pump.

To obtain the data, the vacuum pump is constantly running during an experiment. After discharge of the system, the individual valves for each manifold are opened and closed at predetermined times. Based on the time a given valve is open and the flow rate, the volume of air traveling through the drying tube is calculated. The drying tube is weighed after the experiment and compared to its weight prior to the experiment to determine how much water was absorbed. With this information, the concentration of water in the air can be calculated.

This enables air sampling for water concentration at five different locations at nine different times. With this information a direct comparison of the water concentration can be plotted as a function of time and as a function of location.

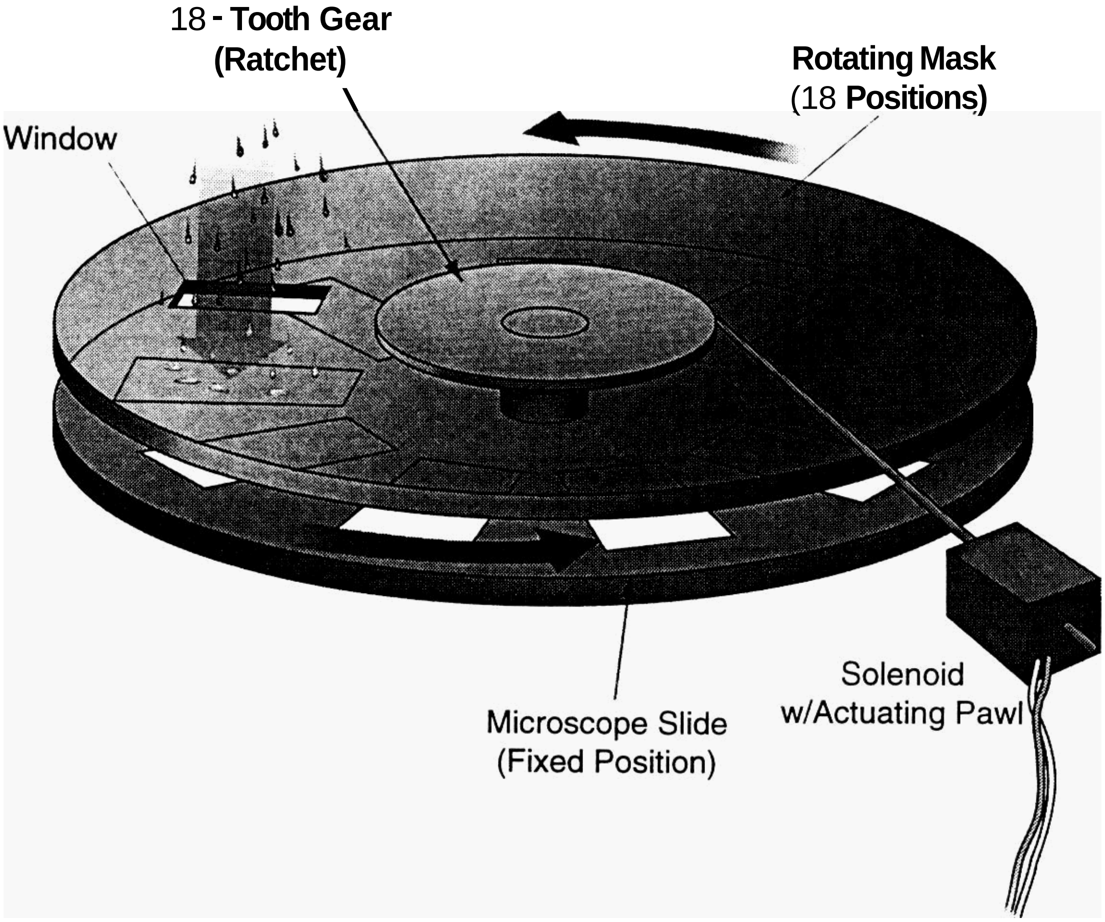

Figure 4 Microscope Slide Carousel

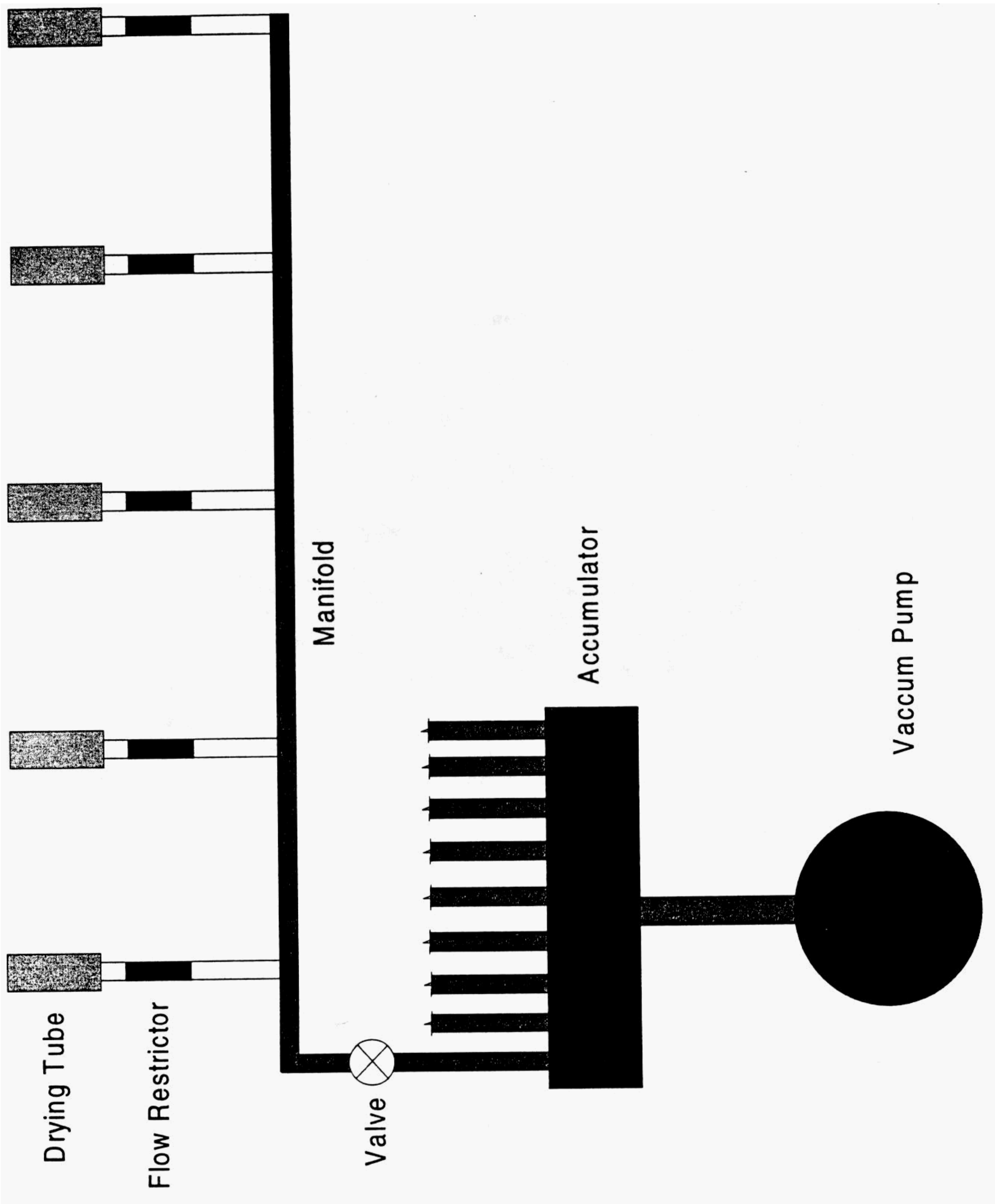

Figure 5 - Drying Tube Schematic

AGENTS

As noted it is believed a fine mist of water is an excellent fireextinguishing agent. However, the possibility of the water freezing is not out of the question. For this reason other water-based agents will also be investigated for use with this device. Prior work has indicated that sprays of a 60 weight-percent solution of potassium acetate in water or a 60 weight-percent solution of potassium lactate in water is 10 to 20 times more effective than water at extinguishing pool fires.' Both solutions have a freezing point of approximately –60°C.

PROGRESS

Initial experiments have been performed to test the system. For these tests both of the fire extinguishing bottles were filled with 15-lbs of CO_2. Upon activation of the solenoid valves, the two bottles discharged. The time required to discharge the bottles was approximately 45 s. This was using the system as described with the ½-inch diameter ISG mixer with five elements present.

The temperature of the CO_2 was also measured as it exited the nozzle. The temperature averaged -65°C. As expected with these temperatures, it is possible the water could freeze at some point, creating a temporary blockage in the system. For this reason experiments with a low-freezing-point water-based material is also planned.

FUTURE WORK

Future work will entail determining the most effective configuration. This will require experimenting with different mixing chambers. The ½-inch diameter ISG will be used. Depending on the results of the %inch ISG mixer, other diameter ISG mixers will be used. The number of mixing elements will also be vaned to determine how the number of layers created affects the dispersion of the water mist.

Various commercially available static mixers are available. Different mixers will be investigated to determine their ability to create a mixture suitable for use with this device. Nozzle design will also be investigated to determine how the nozzle affects the output of the water mist.

Other parameters of the device will also be vaned to determine the optimum configuration. Gases other than CO_2 will be investigated to determine their ability to pressurize the waterhater-based solution. A possible gas for this purpose is nitrogen. Vaporizable liquids other than CO_2 for use as the propelling agent will also be investigated. One possible vaporizable liquid is FE25 due to its favorable normal boiling point.

After the preliminary investigation of mixing chambers, nozzle designs, various gases, etc, tell-tales fires will be created throughout the enclosure and the system will be discharged. The device's ability to extinguish the tell-tale fires will be noted. This will be repeated with the configurations that looked promising based on the data collection from the investigation of the system parameters.

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[2] Finnerty, A. E., McGill, R. L., Slack, W. A., "Water-Based Halon Replacement Sprays," ARL-TR-I 138, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, July 1996